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Original Article

Side-to-side difference in dynamic unilateral balance ability and pitching performance in Japanese collegiate baseball pitchers

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Abstract. [Purpose] To evaluate the side-to-side difference in dynamic unilateral balance ability and to determine the correlation of the balance ability with pitching performance in collegiate baseball pitchers. [Subjects and Methods] Twenty-five Japanese collegiate baseball pitchers participated in this study. Dynamic balance ability during a unilateral stance was bilaterally evaluated using the star excursion balance test (SEBT). The pitchers threw 20 fastballs at an official pitching distance; the maximal ball velocity and pitching accuracy (the number of strike/20 pitches × 100) were assessed. Side-to-side difference in scores of SEBT was assessed using a paired t-test. Correlations between SEBT scores and pitching performance were evaluated for both legs using a Pearson's correlation analysis. [Results] The pivot side showed significantly higher score of the SEBT in the anteromedial direction than the stride side. On the other hand, the SEBT scores in the pivot and stride legs did not have significant correlations with maximal ball velocity and pitching accuracy. [Conclusion] These findings suggest that marked side-to-side difference does not exist in the dynamic unilateral balance ability of collegiate baseball pitchers and that the dynamic unilateral balance ability of each leg is not directly related to maximal ball velocity and pitching accuracy.

Key words : Dynamic balance ability, Baseball pitcher, Pitching performance

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INTRODUCTION

The physical characteristics of athletes, and their relationship with athletic performance, need to be considered in the process of athletic rehabilitation. Several studies[1–4)] have reported that the flexibility and strength of the lower extremities are important in injury prevention and/or performance enhancement of baseball pitchers. In addition, dynamic postural control during a unilateral stance is also thought to be a significant physical factor for stabilization during the throwing motion in baseball pitchers[5–8)]. Endo et al. investigated the correlation of dynamic unilateral balance ability with lower extremity tightness[6)] or shoulder/elbow injuries[7)] in junior high school baseball players. However, the relationship between dynamic unilateral balance ability and pitching performance in baseball pitchers has not been fully investigated.

Baseball pitchers move their body toward the catcher while balancing on the pivot leg (leg on the same side of a throwing arm) until the instant the stride foot contacts the ground. Thereafter, the pitchers rotate their trunk and throwing arm while balancing on the stride leg (leg on the opposite side of a throwing arm). Thus, for baseball pitchers, dynamic unilateral balance ability is thought to be important, not only for smooth energy transfer from the pivot leg to the stride leg, trunk, throwing arm, and finally, to the ball, but also for supporting the powerful motions of the trunk and throwing arm during throwing motion[2, 9)]. However, the detailed relationship between dynamic balance ability of each leg and pitching performance, measured through parameters such as ball velocity and pitching accuracy, is not clear. Additionally, a consensus has not been obtained regarding the side-to-side difference in a pitcher's dynamic unilateral balance ability.

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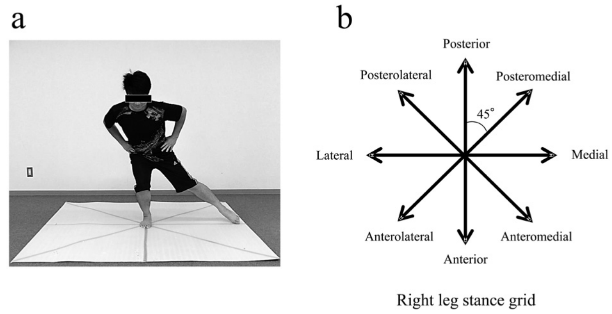

Fig. 1. Star excursion balance test.
The medial reach with the left lower extremity is performed while balancing on the right lower extremity (a). The testing grid for the star excursion balance test in the case of right leg stance (b). The eight lines are named based on the direction of reach in relation to the stance leg.

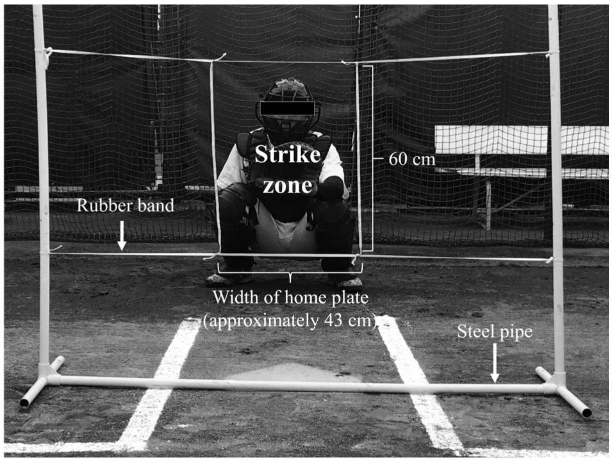

Fig. 2. A hand-made apparatus for the measurement of pitching accuracy.
The strike zone (60 cm × 43 cm) of the apparatus corresponds to that of a batter approximately 175 cm tall.

The purpose of this study was to compare the dynamic unilateral balance ability between the pivot and stride legs in collegiate baseball pitchers. In addition, we aimed to assess the correlation between dynamic unilateral balance ability and pitching performance (maximal ball velocity and pitching accuracy). These data would be useful to clinicians when constructing training and rehabilitation programs for baseball pitchers. Our hypothesis was that baseball pitchers show asymmetrical dynamic unilateral balance ability between the pivot and stride legs, and a positive correlation between dynamic unilateral balance ability and pitching performance.

SUBJECTS AND METHODS

Twenty-five Japanese overhanded collegiate male baseball pitchers (right-handed, n=19; left-handed, n=6; mean and standard deviation [SD]; age, 19.4 ± 1.0 years; height, 177.0 ± 4.3 cm; weight, 72.5 ± 4.6 kg) participated in this study immediately after the end of their autumn baseball league games. All participants had no pain and discomfort in their body at the time of measurement and no previous history of extremity surgery or injury. This study was approved by the Ethical Committee of Jobu University (No.15-B01) and conformed to the current Declaration of Helsinki guidelines. After the purpose, potential benefits and risks, and examination procedures of this study were explained, written informed consent was obtained from each subject.

We used the star excursion balance test (SEBT) to evaluate dynamic unilateral balance ability of the pitchers. The SEBT, a multidirectional test of dynamic postural control, involves balancing on one lower extremity and using the other one to reach the maximum distance in eight different directions (Fig. 1). The foot position was controlled by aligning the center of the stance foot with that of the grid. This position was marked with a piece of tape to ensure accurate repositioning between trials. The subjects were instructed to lightly touch along the chosen line as far as possible with the most distal part of their reach foot while maintaining a single-leg stance and then return to the start position with a bilateral stance. Errors were recorded if the subject's hands did not remain on the waist, the position of the stance foot was not maintained, the heel did not remain in contact with the floor, the subject lost his balance during trial, or the reach lower extremity provided considerable support in the maintenance of upright posture. If these errors occurred, the subject performed the trial from the start position again. The subjects performed two practice trials in each direction on each lower extremity. After the practice trials, the subjects performed three trials in each of the eight directions on both lower extremities (30 s of rest between trials); the orders of reach direction and tested lower extremity were randomly decided. The length of the lower extremity was measured from the anterior superior iliac spine to the distal tip of the medial malleolus using a standard tape measure while the subjects lay in a supine position and was used to normalize the excursion distance (reached distance/lower extremity length ×100). The mean of the three trials in each direction was calculated.

After an adequate warm-up, each subject threw 20 fastball pitches at maximum effort from a wind-up position at a rate of 1 pitch every 15 s from a pitching mound to a catcher (the distance between a pitcher's plate and a home plate was 18.44 m: official pitching distance). The subjects were instructed to aim at the strike zone of a hand-made apparatus located in front of the home plate (Fig. 2). The strike zone of the apparatus corresponded to that of a batter approximately 175 cm tall. Pitching accuracy was evaluated by a passing rate of strike zone in 20 pitches (the number of strike/20 pitches × 100). In addition, ball velocity was measured using a radar gun (HP-2, TOA SPORTS MACHINE Inc., Osaka, Japan) from behind the catcher. The

Table 1. Comparison of star excursion balance test score between the pivot and stride legs in collegiate baseball pitchers (Unit: %)

	Pivot-leg stance	Stride-leg stance	Effect size
Anterior	80.9 ± 3.7	80.8 ± 4.9	d=0.03
Anteromedial	91.5 ± 4.8*	89.4 ± 4.8	d=0.42
Medial	100.2 ± 5.4	99.0 ± 6.9	d=0.18
Posteromedial	107.1 ± 6.0	106.9 ± 6.4	d=0.04
Posterior	110.2 ± 6.5	110.4 ± 6.2	d=0.04
Posterolateral	102.1 ± 8.1	102.6 ± 7.6	d=0.07
Lateral	84.0 ± 11.8	84.2 ± 10.2	d=0.02
Anterolateral	67.9 ± 3.3	68.5 ± 4.4	d=0.15

Data are expressed as mean ± standard deviation.
*$p<0.05$.
In the case of right-handed pitcher, pivot-leg stance means right-leg stance.

Table 2. Pearson's correlation coefficients (r) between star excursion balance test score and pitching performance in collegiate baseball pitchers

	Pivot-leg stance							
	Anterior	Anteromedial	Medial	Posteromedial	Posterior	Posterolateral	Lateral	Anterolateral
Ball velocity	−0.132	−0.170	−0.088	−0.160	0.019	−0.043	0.071	−0.098
Pitching accuracy	0.124	−0.035	0.055	−0.095	0.010	−0.045	0.041	0.052
	Stride-leg stance							
	Anterior	Anteromedial	Medial	Posteromedial	Posterior	Posterolateral	Lateral	Anterolateral
Ball velocity	0.017	−0.057	0.004	0.062	0.112	0.052	0.117	−0.036
Pitching accuracy	0.095	0.002	−0.057	−0.081	−0.170	−0.129	−0.090	0.015

fastest pitch passing the strike zone was used for analysis.

The mean and SD were calculated for all variables. SEBT scores were compared between the pivot and stride legs of the subjects by using a paired t-test. In addition, effect sizes (Cohen's d) were calculated and evaluated as trivial (0–0.19), small (0.20–0.49), medium (0.50–0.79) and large (0.80 and greater)[10]. The pivot and stride legs were defined as the leg on the same side as the throwing arm and the leg on the opposite side of the throwing arm, respectively. In addition, Pearson's correlation coefficients (r) was used to evaluate the correlations between SEBT scores and pitching performance (maximal ball velocity and pitching accuracy) in both lower extremities. Statistical analysis was performed with IBM SPSS statistics 23. Statistical significance was set at $p<0.05$ for all analyses.

RESULTS

Table 1 shows the SEBT scores in eight different directions in both lower extremities. The value of the pivot-leg stance was significantly greater than that of the stride-leg stance in the anteromedial direction ($p=0.017$, $d=0.42$).

Table 2 shows the correlations between SEBT score and pitching performance. The maximal ball velocity and pitching accuracy were 133.9 ± 6.5 km/h and 49.8 ± 22.3%, respectively. The SEBT scores did not have significant correlations with maximal ball velocity and pitching accuracy in the pivot and stride legs.

DISCUSSION

In the SEBT, the pivot leg showed a significantly greater value than the stride leg in the anteromedial direction. This finding may be partly attributed to the throwing movement pattern in which the pitcher takes a stride toward the target while balancing on the pivot leg. However, the small side-to-side difference may not be clinically significant. In addition, we should note that the pivot-leg stance did not have significantly greater values than the stride-leg stance in the medial and posteromedial directions, which are also the directions of hip abduction for the stride leg. Furthermore, no significant side-to-side difference was found in any directions except for the anteromedial direction. It is possible that, unlike the glenohumeral range of motion[11, 12], dynamic unilateral balance ability does not display a significant side-to-side difference because the lower extremities are not used unilaterally as the glenohumeral joint is, during throwing motion. Thus, we may not need to consider the side-to-side difference in dynamic unilateral balance ability when constructing training and rehabilitation programs for baseball pitchers. Although the SEBT has been used to evaluate dynamic postural control during a unilateral stance, the score is closely associated with the flexibility and strength of the lower extremities (the hip, knee, and ankle joints)[6, 7, 13–15].

Therefore, the collegiate baseball pitchers who participated in this study might not have had marked side-to-side differences in the flexibility and strength of the lower extremities. One of the causes for this can be bilateral physical training of the lower extremities, such as squatting, jumping, and running, in daily practices. However, this opinion is only speculative because we did not assess the flexibility and strength of the lower extremities. To date, very few attempts have been made to investigate the side-to-side difference in dynamic postural control during a unilateral stance in baseball pitchers. Further research on this issue is needed.

Baseball pitchers balance on the pivot leg until the instant their stride foot contacts the ground, and thereafter, balance on the stride leg during throwing motion. Thus, dynamic postural control during a unilateral stance has been suggested as being one of the important physical factors that influence pitching performance[2]. However, contrary to our expectations, dynamic unilateral balance ability of the pivot and stride legs in collegiate baseball pitchers did not positively correlate with maximum ball velocity and pitching accuracy. One of the causes of these results may be the complexity of baseball pitching, which requires coordinating joint movements of the whole body. For instance, baseball pitching requires a high degree of skill to smoothly transfer large amounts of energy through the kinetic chain to the ball in order to increase the ball's velocity and also to consistently release the ball at the proper position in order to enhance pitching accuracy. Thus, the integrity of the throwing movement pattern (throwing skill) might affect pitching performance; however, a biomechanical approach will be needed to resolve this issue. As described above, the SEBT score reflects not only unilateral balance ability but also the flexibility and strength of the lower extremities[6, 7, 13–15]. Therefore, physical factors other than balance ability would need to be considered when we interpret the SEBT score. However, Marsh et al.[5] suggested that reduced vestibular input utilization causes a decline in dynamic body balance, resulting in decreased pitching accuracy. The vestibular system functions to maintain body balance by monitoring the spatial position of the head and to stabilize gaze while the head is moving (the vestibule-ocular reflex)[16]. Increased head motion may adversely affect the utilization of vestibular input during throwing motion. Therefore, head stability during throwing motion may be important for pitching accuracy[5]. Additional data are necessary to understand the relationship between dynamic balance ability during a unilateral stance and pitching performance of baseball pitchers.

The present study has a few limitations. First, we did not measure the flexibility and strength of the lower extremities, which have been previously reported as being closely associated with the SEBT score. Second, we did not determine the relationship between dynamic unilateral balance ability and the biomechanical parameters (kinematics and kinetics) of the throwing motion. Third, we included only collegiate baseball pitchers. In future, comparisons among players of various age groups (e.g., preadolescent vs. adolescent) and competitive levels (e.g., amateur vs. professional) would lead to a better understanding of the relationship between dynamic unilateral balance ability and pitching performance. However, the protocol for SEBT (three trials in each of the eight directions on both lower extremities) used in the present study may be too severe for physically immature baseball pitchers.

In collegiate baseball pitchers, a pronounced functional difference between the pivot and stride legs was not found in dynamic balance activity during a unilateral stance. Therefore, dynamic unilateral balance ability may not show marked functional adaptation to asymmetrical motions during throwing motion. In addition, the findings of this study suggest that each dynamic unilateral balance ability of the pivot and stride leg is not directly related to maximal ball velocity and pitching accuracy in collegiate baseball pitchers.

Conflict of interest

We have no financial and personal relationship with other people or organization that could inappropriately influence or bias our work.

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